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# TITLE: Finite Volume Model For Coupled Simulation Of 1D-river Flow, 2D-overland Flow and 3D-variably Saturated Flow


***ABSTRACT***

Surface-water, vadose zone and groundwater are linked components of a hydrologic continuum. The coupled processes interact at a variety of spatio-temporal scales influenced in part by the heterogeneity in topography, climate, land-use and hydrogeology. In order to comprehensively and accurately capture the interaction between different components of a hydrologic continuum, full physical coupling, “natural” numerical coupling and parsimonious but accurate data coupling is needed. Here we present a physically based, spatially distributed hydrologic model that incorporates all the three coupling strategies.

Physical coupling between 1D river flow, 2D surface overland flow and 3D variably saturated subsurface flow has been performed by implementing continuity assumption in head and fluxes at respective river-surface-subsurface interfaces. All the physically coupled components are numerically coupled through semi-discrete form of ordinary differential equations, which define each hydrologic process, using a cell-centered finite volume based approach. Multidimensional reconstruction of state variables on each control volume has been employed to achieve second-order spatial accuracy and to prevent nonphysical oscillations. The fully implicit BDF method with Newton-Krylov iteration is used to solve for all the state variables simultaneously at each adaptive time steps thus providing robustness, stability and accuracy. The accurate data coupling is aided by the use of constrained unstructured meshes, which have distinct advantages over structured grids, as they are able to conform to arbitrary geometries and their concentration can be adaptively changed in high gradient regions or in regions of particular interest in a flow field. The spatial adaptivity of the decomposed domain and temporal adaptivity of the numerical solver facilitates capture of varied spatio-temporal scales that are inherent in hydrologic process interactions.

The surface flow numerical model is based on diffusive wave approximation of hyperbolic Saint Venant equations thus resulting in parabolic equations which are easier and faster to solve numerically. Subsurface flow simulation is based on solution of the complete three-dimensional nonlinear Richards equation throughout the whole flow domain. The model is able to simulate subsurface flow in heterogeneous and anisotropic geologic settings and has the capability to simulate pumping and delayed yield effects.

Model performance is evaluated by reproducing the results of controlled numerical experiments for each individual processes and their interactions with that obtained from models such as VS2D, ModHMS, ParFlow and InHM. The numerical results obtained from the model are in good agreement with the ones presented in existing literature.

The community hydrologic model and the associated domain decomposition toolsets developed in this effort are open source and can be use by anyone for research purposes